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Using aircraft based high reflectance signatures and specific absorption coefficients to remotely estimate coastal water quality.

In: Proceedings of the Second International Airborne Remot Sensing Conference and Exhibition, San Franciso, California, 24-27 June 1996. Pages III647-III-656.

AUTHOR(S)
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ORIGINATING NASA ORGANIZATION
Kennedy Space Center Biomedical Office

PERFORMING ORGANIZATION (If different)
Dynamac Corporation

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USING AIRCRAFT BASED HIGH RESOLUTION REFLECTANCE SIGNATURES AND SPECIFIC ABSORPTION COEFFICIENTS TO REMOTELY ESTIMATE COASTAL WATER QUALITY*

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Quantitative analysis of chlorophyll-a, dissolved organic matter (DOM), and total suspended sediments (TSS) was conducted using reflectance second derivative spectra and specific absorption coefficients measured from a solid state spectrograph. The water samples were placed in a 50 cm pathlength cylindrical cuvette from which absorption coefficients were measured. Various algorithms were tested to calculate the specific absorption coefficient for chlorophyll-a, seston, and DOM components measured as dissolved organic carbon. This instrumental system was used to relate measured absorption coefficients with water reflectance signatures measured from the same spectrograph mounted within the nose of a PA34-200T Seneca II. The methods demonstrate the value of high spectral resolution signatures to estimate concentrations of various water quality parameters from aircraft in conjunction with absorption coefficients.

1.0 INTRODUCTION

Remote sensing is defined by Lillesand and Kiefer (1987) as "the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by the device that is not in contact with the object, area, or phenomenon under investigation". This scientific approach is used in environmental remote sensing. An example is the use of data collected by satellite platforms equipped with remote sensing systems such as SPOT or Landsat, or aircraft equipped with spectrometers (e.g. AVIRIS). There has been significant amount of research in remotely determining water quality parameters in open waters such as temperature, chlorophyll, suspended sediments, and, to a lesser degree, dissolved organic matter (D.O.M.). Such research is applied not only in freshwater systems but in monitoring coastal

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and estuarine processes. Remote sensing research in coastal waters has not been as prominent as deep ocean waters. This is because of the optical complexity and the diversity of the water quality parameters in these near shore water systems and characterized as turbid water systems. One of the parameters of interest is chlorophyll-a. Some researchers may consider that chlorophyll-a is more readily measured by remote sensoring devices in deep oceanic waters, however, as one approaches coastal waters, the measurements are less accurate and precise due to the presence of suspended matter and DOM. This is because DOM absorbs light within the same spectral range as chlorophyll-a. Several methods have been proposed to discriminate these different signals. One of these methods is derivative spectrometry. Bostater (1991) has developed a technique of optimal "passive" ambient correlation spectroscopy (OPACS) based upon the work of Grew (1981) which involves in the selection of bands and band widths for estimation of water quality parameters and associated coefficients based upon "passive" hyperspectral sensor system data.

Knowledge of the radiance distribution in water is important in accurately predicting various water quality parameters from remote sensing data. A two-flow model has been analytically solved (Bostater et al, 1994) from the radiative transfer equations of irradiance. This model describes the light attenuation in a water column by inherent optical properties of the water (absorption and backscatter). It also describes the influence of the bottom reflectance as well as other apparent optical properties of the water (i.e. sun angle, specular light component just to name a few).

This model can be used for testing in-situ water reflectance measurements as well as airborne or satellite remote sensing measurements of reflectance. The ultimate goal in water quality remote sensing is to infer the concentrations of water quality parameters from the reflectance data. For this model to be applicable in coastal and estuarine systems, one needs to know the specific absorption coefficients, the specific backscattering coefficients, and bottom reflectance signatures. An absorption cuvette (Model BHS CC-Abs-110b) has been developed (Bostater and Gimond, 1995) which allows one to measure absorption coefficients for water types ranging from turbid estuarine waters to clearer, optically deep coastal waters. The specific absorption coefficients can be determined by utilizing the absorption spectra along with independently measured concentrations of various water quality parameters. The technique builds upon the techniques of Yentsch (1962).

In developing and applying the two-flow equations, it is important to relate the absorption spectra to the reflectance spectra. In doing so, errors can occur when different sensors are used in measuring both signatures. A novel method is measuring both of these spectra with the same instrument. Bostater and Gimond (1995) demonstrated this approach which employs the use of the same instrument for both the absorption measurements as well as the ship or aircraft based reflectance measurements. Reflectance data (in-situ and airborne) as well as absorption data is thus collected with the same sensor. We report in this paper the results of determinations of specific absorption for suspended sediments, chlorophyll-a and dissolved organic matter in Florida's Space Coast waters by performing regressions between various water quality constituents and second derivative estimators using absorption coefficients and reflectance spectra.

2.0 METHODS

Water samples were collected and analyzed at nine stations. These stations varied from turbid estuarine to coastal waters. In-situ above surface reflectance measurements and laboratory based absorption scans were made using the same solid state spectrograph (SE590) with a 252 channel high sensitivity linear diode array. Water samples were collected and analyzed for chlorophyll-a, total suspended sediments (TSS), and dissolved organic carbon (DOC) (Katz et al, 1954).

Chlorophyll-a analysis was accomplished by using two methods: fluorometric (Yentsch et al,1963) and spectrophotometric (Rott, 1980) methods. These two chlorophyll-a analysis methods were performed in order to test the reliability of these methods in the highly colored water in the Banana River. The chlorophyll-a samples were filtered in-situ onto 0.7 μm pore size Whatman CF/C glass fiber pads then placed in the dark with dry ice so as to prevent any degradation of the pigments. The filter pads were processed, as described by Yentsch (1963) and Standard Methods (1989), and analyzed using a Turner 10-000r fluorometer and a Shimadzu UV-160 spectrophotometer. Samples were analyzed on both instruments simultaneously. Spinach extracted chlorophyll-a purchased from Sigma Corporation (number C-5753) was used to calibrate both instruments.

Whole water samples were filtered using 0.45 μm pore size Gelman GN-6 metricel membrane filters. For suspended sediments, pre-weighed filtered pads were placed in a dessicator for 96 hours then weighed again. The difference between pre-filtered and post-filtered pad weights with knowledge of the value of water filtered was used to calculate TSS (seston, mg/l).

Total organic carbon (DOC) was determined using the combustion-infrared method (Katz et al, 1954). Whole water was filtered on Whatman 934-AH glass microfibre filters (4.7 cm). This procedure provides dissolved organic and dissolved inorganic carbon (total dissolved carbon).

The stations in estuarine waters were collected in the Banana River located in central eastern Florida. Figure 1 shows the locations of these stations. Two other stations were sampled in the Atlantic Ocean about 20 miles offshore aboard Florida Tech's *R/V Delphinus*. Table 1 tabulates the station identifications along with their corresponding dates and water depths.
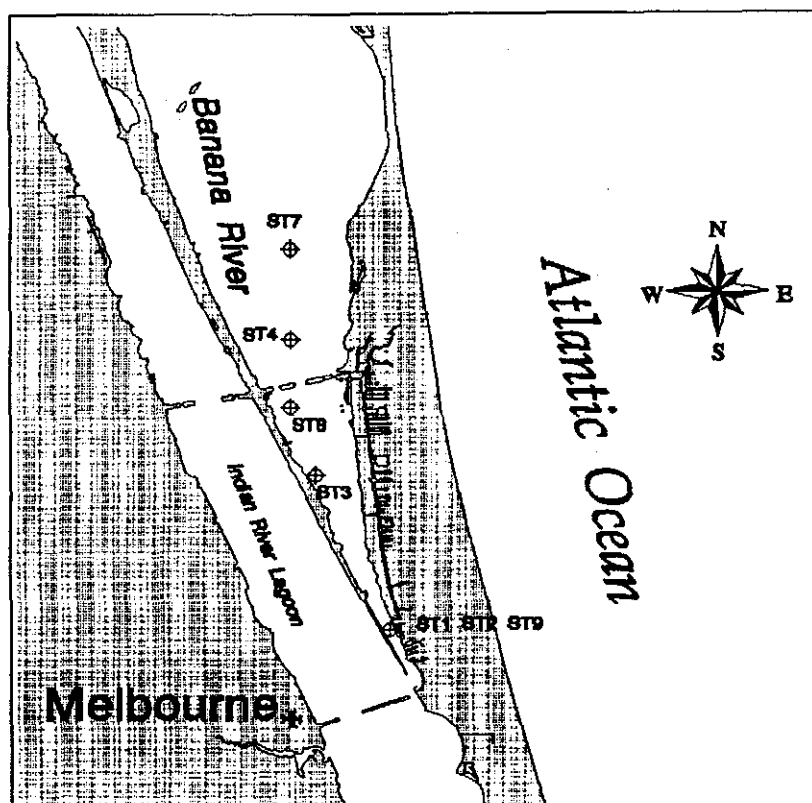

Figure 1. Location of stations in Lagoon.

Table 1. Water sampling stations profile.

station ID	date	water depth (m)
sta1	1/30/96	7
sta2	1/30/96	1.9
sta3	1/30/96	3.2
sta4	1/30/96	3.2
sta5	2/14/96	34
sta6	2/14/96	34
sta7	2/26/96	2.5
sta8	2/26/96	3.5
sta9	2/26/96	1.3

3.0 RESULTS

Figure 2 shows the measured in-situ reflectance spectra just above the water for the nine stations using the SE590 spectrograph.
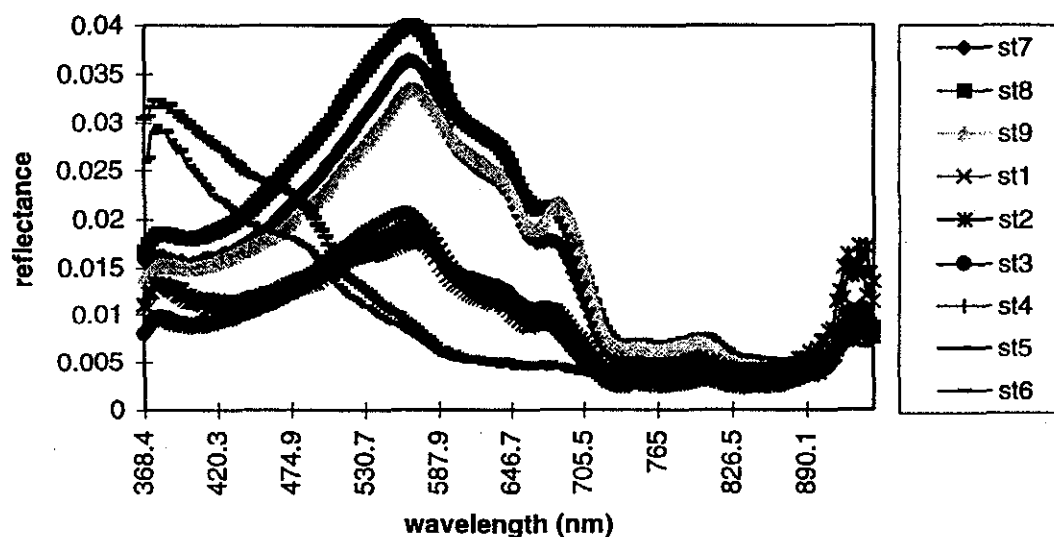

Figure 2. Spectral reflectance curve for all nine stations

Absorption scans were made for these same waters shortly afterwards. The absorption coefficients were obtained from:

$$a_s = 2.3 \ (log(I_o/I_s)) \ / \ L \qquad (1)$$

where a_s is the absorption coefficient (m^{-1}), 2.3 is the conversion from a log_{10} to a natural log_e, I_o is the transmitted light through the reference tube $(W/m^2.sr)$, I_s is the transmitted light of the sample through the sample cuvette $(W/m^2.sr)$, and L (m) is the pathlength of the tubes which is 0.5 meters.
Figure 3 shows the absorption spectra for the absorption coefficient (1/m) for the whole water samples.
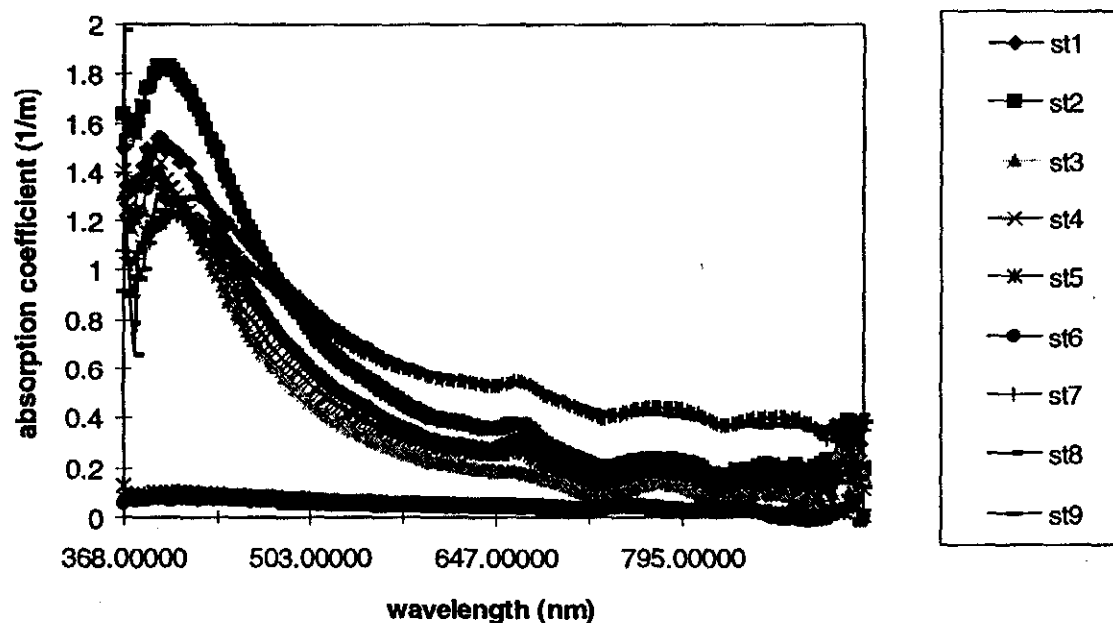
Figure 3. Absorption spectra for whole water samples for the nine stations.

Water samples from these stations were filtered onto .45 μm Millipore pads. The filtrate was recovered than scanned for absorption. The filtrate is taken to be the dissolved organic matter component of the water. Figure 4 shows the resulting spectra for the dissolved water and is considered to reflect the DOM at each location.

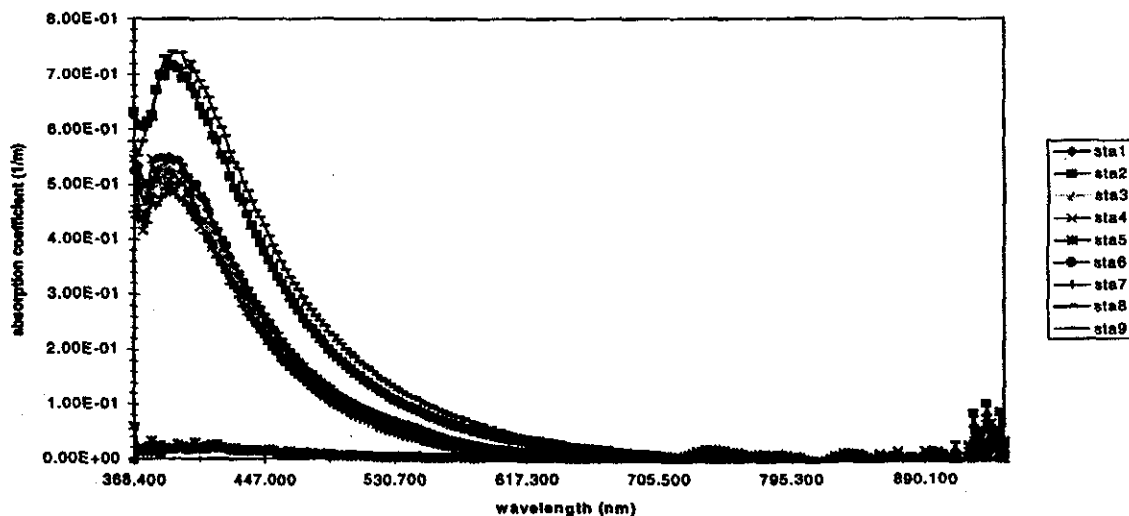The TSS absorption spectra was calculated by subtracting the DOM spectra from that of the whole

Figure 4. Absorption spectra for DOM for all stations.
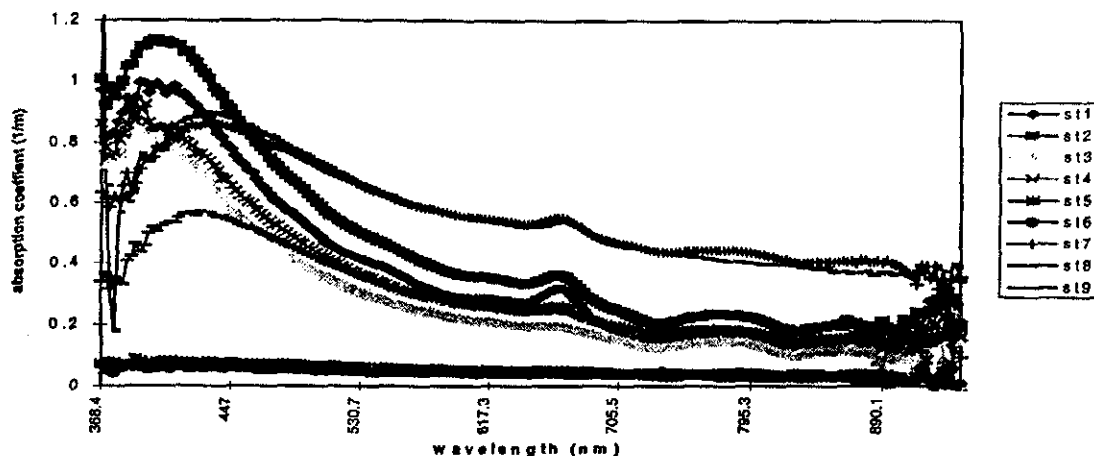
Figure 5. Calculated absorption spectra for TSS for all stations.

water spectra and these are shown in Figure 5.

Single band correlation was calculated between TSS concentrations and whole water absorption spectra and calculated TSS spectra at all wavelengths. Single band correlation was also calculated between dissolved organic carbon concentration and DOM spectra at all wavelengths. Figures 6 through 8 represent these correlations. These spectral correlograms represent the relative quality of the calculated specific absorption coefficients as a function of wavelength obtained from the slope of the zero-slope regression results.

OPACS (Bostater,1991) was used to calculate the second derivative inflection estimator of the whole water spectra then the optimal bands were objectively selected for estimation of the chlorophyll-a specific absorption coefficients from absorption coefficients directly by correlating to chlorophyll-a concentrations to the inflection estimator.

Figure 11 shows the reflectance signatures of three of locations measured from an aircraft flight along the Banana River. These reflectance scans are plotted with their respective absorption spetcra.
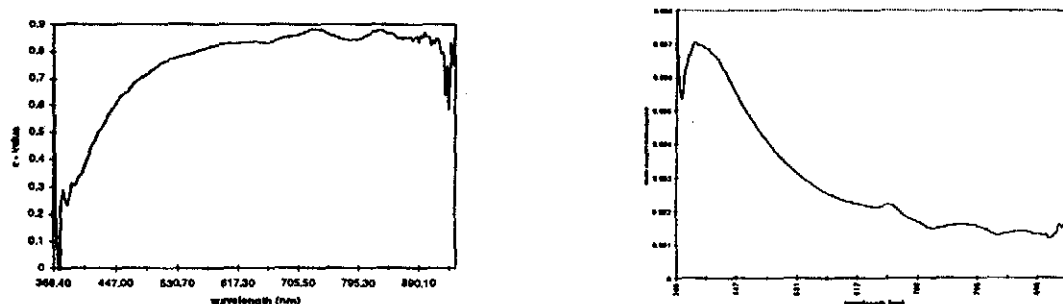
Figure 6. Correlation (zero intercept regression) value for TSS concentration versus whole water absorption spectra (left) with the resulting calculated suspended particulate matter specific absorption coefficients in m²/mg(right) for Space Coast waters.
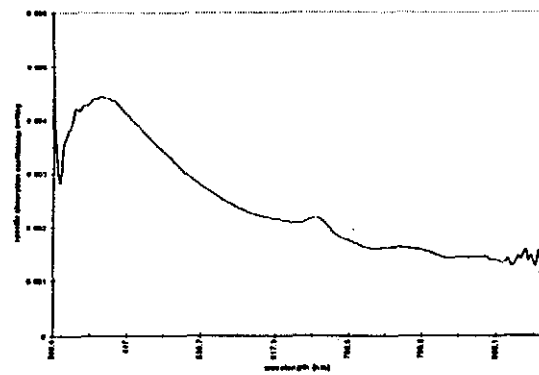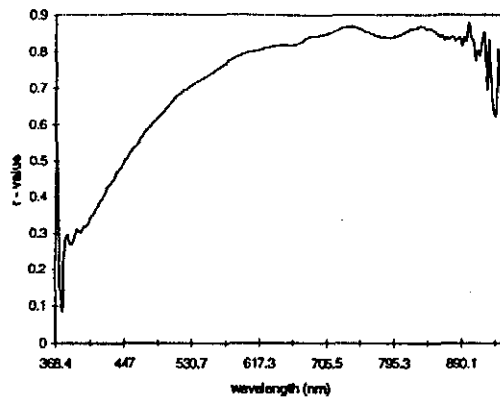
Figure 7. Correlation value for TSS concentration versus calculated TSS absorption spectra (left) along with the calculated specific absorption coefficient in m²/mg(right).
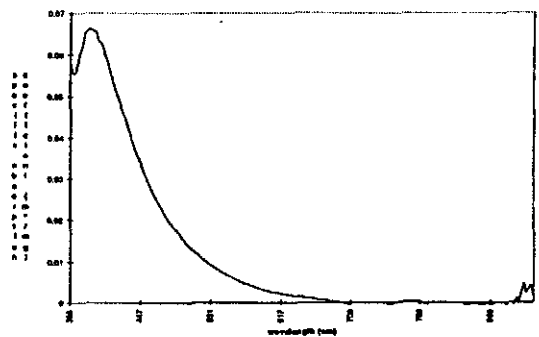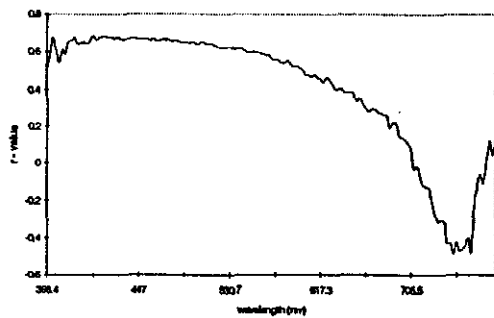

Figure 8. Correlation value for DOC versus DOM absorption spectra (left) along with the calculated specific absorption coefficient in m²/mg (right).
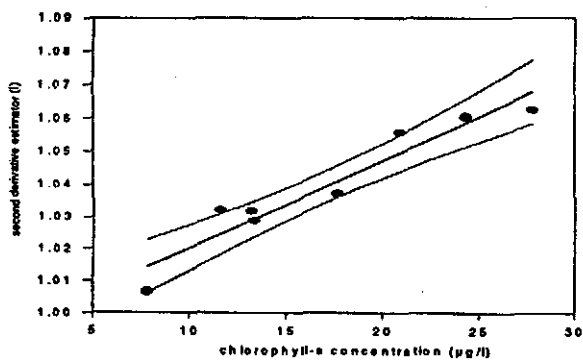

Figure 9. Correlation (95% confidence intervals) for chlorophyll-a concentration versus the three band inflection versus absorption scan at bands centered at 508.3, 530.7, and 494.3.

4.0 DISCUSSION

The peaks and troughs of the reflectance spectra and the absorption spectra of the water samples agree with respect to wavelengths as expected. This is important in order to test the two-flow model using aircraft remote sensing data.

The chlorophyll-a peaks are evident in both the reflectance spectra and the absorption spectra (TSS and whole water). Bostater's passive correlation spectroscopy technique (1991) was utilized to determine the best three bands for chlorophyll-a concentrations for both the absorption spectra and the reflectance spectra. The bands centered at 596.7, 646.7, and 587.9 were objectively selected by OPACS data processing software using reflectance scans. Likewise, three bands centered at 508.3, 530.7, and 494.3 were objectively selected by OPACS from the absorption scans. These band selections agree with the positions of the various inflection points found in the chlorophyll-a absorption spectra (Bostater and Gimond, 1995). High correlation values occurred between these band ratios and the concentration values for chlorophyll-a (r = .91 and r = .95 for reflectance and absorption spectra respectively). Figure 9 indicates the correlation value for chlorophyll-a concentration versus the three band inflection ratio derived from the absorption scan. The selected bands were used to extrapolate chlorophyll-a concentrations from the reflectance signatures collected from the aircraft. This data is graphed and shown in Figure 11 along with the map of the reflectance transect flown by the airborne platform (Figure 10).

Good correlation occurred between TSS concentrations and both the whole water spectra and the calculated TSS spectra. This would indicate that TSS concentrations could be extrapolated from whole water multispectral scans with confidence. Also, spectral absorption peaks for TSS appear to occur at higher wavelengths than the DOM absorption peaks. This would indicate that discrimination between these two water quality parameters could be possible from airborne remote sensing platform using the techniques described in this paper.

Good correlation also occurred between TOC concentrations and DOM absorption spectra. However, this does not necessarily make inference on the concentration and/or on the presence of various humic substances since the spectral scan of the latter is not only depended on the presence of carbon but also on its structure.

Future studies will involve a greater number of airborne transects over various types of water bodies under various seasonal conditions in order to estimate the variability of the selected bands. This would be indicate of a possible alternate method in analyzing chlorophyll-a in highly colored waters in the Banana River. This methodology could make aircraft remote sensing of highly colored estuarine waters feasible for water quality monitoring. More importantly, the techniques applied provide a powerful set of tools for calibrating and validating satellite based measurements of water quality using future hyperspectral satellite imaging systems.

5.0 CONCLUSION

The use of airborne reflectance signatures in conjunction with the 0.5 m cuvette based (BHS CC-Abs-100b) absorption tube system combined with both the two-flow model and OPACS technique will enable one to make proper inferences on various water quality parameters in shallow and turbid estuarine systems. The preliminary work described in this paper indicate great potential in remote sensing of these

type of waters. Further studies of these waters with the aircraft based remote sensing platform along with the combined use of OPACS and the two-flow model will enable one to develop accurate algorithms to be used with future aircraft or satellite based remote sensors by providing the optimum channels or bands to be used on these platforms.

6.0 ACKNOWLEDGEMENTS

7.0 REFERENCES

C. Bostater, W. Ma, T. McNally, M.Gimond, M. Keller, and M. Pegaz, "Comparison of an Optical Remote Sensing Reflectance Model with Reflectance Signatures Collected From an Airborne Sensor Platform." In The *Proceedings of the Second International Airborne Remote Sensing Conference and Exhibition*, San Francisco, California, 1996.

C. Bostater, *A Remote Sensing Methodology for Shipboard and Aircraft Plarforms Using High Resolution Optical Signatures of Estuarine and Near Coastal Waters*, NOAA/NESDIS Final Project Report, November 29, University of Delaware, 41 pp. 1991.

C. Bostater and M. Gimond, "Methodology Evaluation for Remotely Estimating Water Quality Parameters in Estuarine Waters," In *Proceedings of the European Optical Society and SPIE- The International Society for Optical Engineering (EUROPTO)*, Paris, France, p. 14, 25-28 September 1995.

G. Grew, Real-Time Test of MOCS Algorithm During Superflux 1980. In: *Chesapeake Bay Plume Study, Superflux 1980*, NASA Pub. 2188, Washington, D.C., p. 301-322, 1980.

J. Katz , S. Abrahan, and N. Baker. "Analytical Procedure Using a Combined Combustion-Diffusion vessel: Improved method for Combustion of Organic Compounds in Aqueous Solution." *Anal. Chem.* Vol. 26, page 1503. 1954.

C.S. Yentsch, "Measurement of Visible Light Absorption by Particulate Matter in Ocean," Limnology and Oceanography, vol. 7, pages 207-217, 1962.

Figure 10. Map of transect flown in the Banana River. The transect starts just north of the SR528 Causeway and precedes north near the northern end of the Banana River.
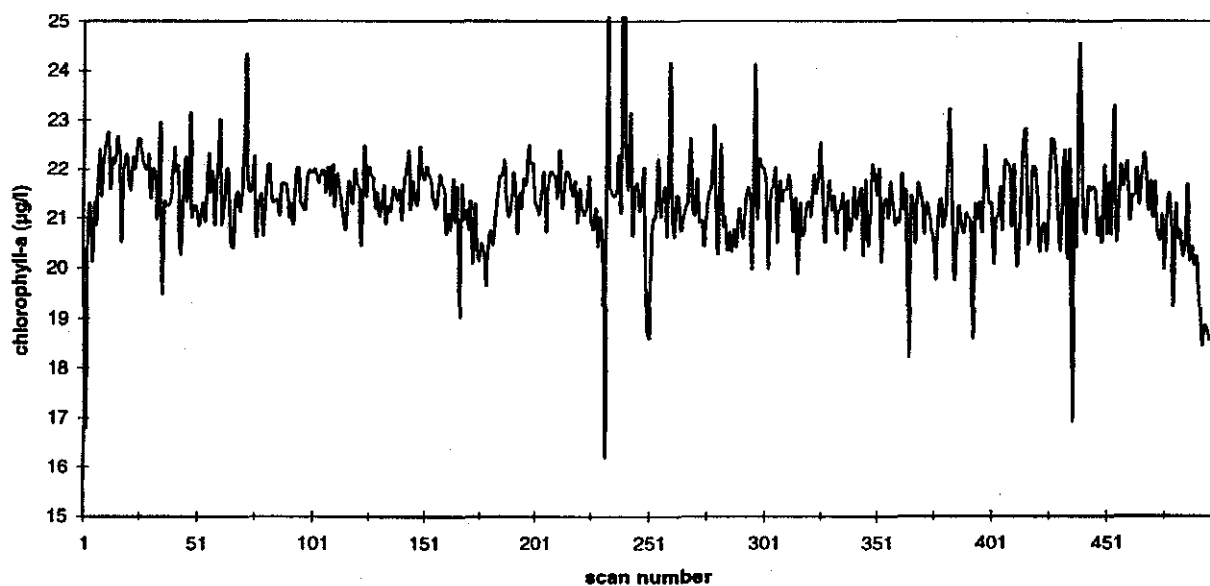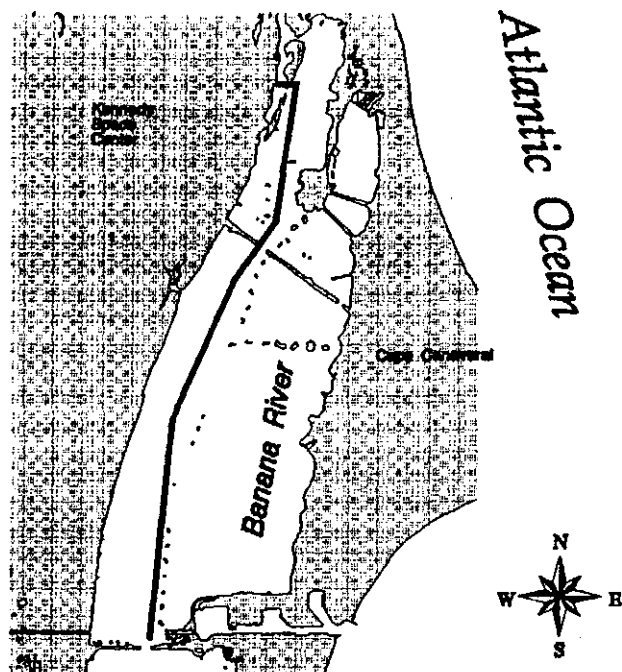

Figure 11. Estimated concentrations of chlorophyll-a for the Banana River from the reflectance second derivative spectra. This reflectance data was collected from a Seneca II equipped with a removable 252 band solid state spectrograph. Scan 1 represents the southern end of the transect diagrammed in Figure 9.
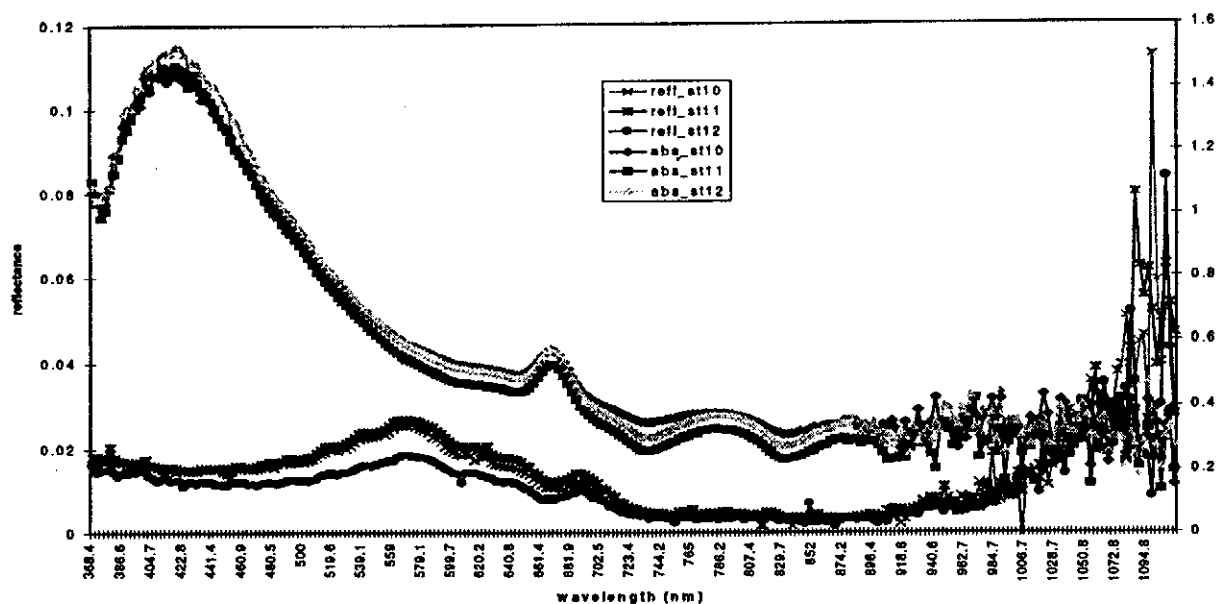
Figure 12. Reflectance and associated whole water absorption spectra for three stations along the North Banana River transect.
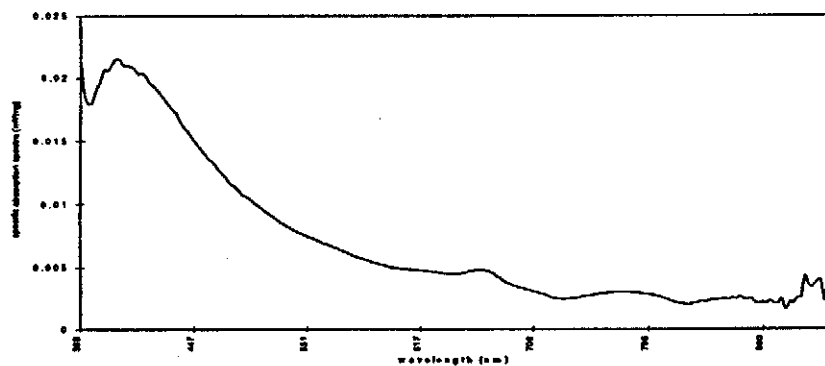

Figure 13. Calculated specific absorption coefficient from absorption scans of chlorophyll-a standards (Bostater and Gimond, 1995). Units are m²/mg.